Off-axis-NOTE-SIM-0010

RPC detector simulation using GMINOS

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Abstract

Data sets with neutrino interactions of different neutrino species in detectors with various longitudinal granularity were generated and stored in Fermilab Mass Storage system. These data sets can be used to optimize the detector design as well as to study the importance of various detector parameters.

1 Introduction

Evaluation of the physics potential of the Off-axis NuMI experiment requires detailed studies of the detector performance in terms of the efficiency of the signal (nue) detection as well as the background (ν_e beam component, ν_μ NC and CC events). This performance depends on the geometry of the detector as well as on various practical details of the detector geometry and construction details (longitudinal and transverse sampling, dead areas, detection efficiency, readout elements geometry, etc.) Expected background rejection approaches a factor of 500, hence the statistical fluctuation of the accepted background events are very large thus necessitating very large sample of the generated events.

2 Detector

Proposed detector is a planar sampling calorimeter: square or rectangular planes of an absorber are interspersed with the planes of active detector in a form of glass Resistive Plate Chambers. Good electron identification necessitates a frequent sampling of the shower development in terms of radiation length X_0. To maximize the expected neutrino events rates it is necessary to maximize the ratio of the radiation length to the average density of the detector. This considerations leads to a conclusion that a low Z absorber is a material of choice.

3 GMINOS

GMINOS is a flexible detector simulation program based on GEANT 3.21. It was developed by R. Hatcher for the MINOS experiment. It is designed as a very general tool which allows simulation of detectors with wide range of geometrical designs. A complete description of the program can be found at the GMINOS web page [1]. The program is a part of a software environment called LABYRINTH, also described there. The data sets described have been generated using a binary version of the GMINOS provided on the linux nodes of the Fermi Unix Cluster, FNALU, and using data cards shown in the Appendix A.

All particles: charged and neutral hadrons, muons, electrons and gamma's were tracked by GEANT down to 100 keV of kinetic energy.

4 Event generator

Neutrino events were generated with a flat distribution of neutrino energies between 1 and 3 GeV, covering the main part of the off-axis neutrino flux produced by π decays. To study the contribution of high energy tails of the spectrum as well as that of the neutrinos produced by K decays additional 'high energy' data sets with the events distributed uniformly between 3 and 20 GeV were generated.

Neutrino events were generated using a NEUGEN event generator[2], derived from the SOUDAN 2 Monte Carlo program. It does generate events charged and neutral current neutrino events with an appropriate mix of (quasi)elastic events, resonances and deep inelastic scattering.

Nuclear cascade part of this event generator was optimized for sub-GeV energy ranges and it was not used for these data sets.

A new version of the NEUGEN event generator is being developed by H. Gallagher. This version will include a coherent π^0 production as well as many other improvements of the simulation of exclusive processes and the transition region to the deep inelastic region. Some data sets using an initial version of this event generator produced, they are identified by a presence of the 'neugen3' string in the file name.

5 Detector Configurations

Detector is assumed to have transverse dimensions of 800×800 cm^2.

Absorber planes were simulated to consist of an air gap followed by a polypropylene layer to yield an average density of the order of 0.65 g/cm^3. To enable optimization of the detector design several thicknesses, 6 cm, 12.5 and 18 cm of the polyethylene absorber plane were simulated. The resulting data files are identified by the string denoting this thickness in the filename.

An active detector was assumed to consist of a plane of glass Resistive Plate Chambers. No transverse granularity of the readout was assumed, instead all 'hits' defined as traversals by charged particles of the active detector volume were are stored in the output file. Properties of the detector are summarized in the following table.

		6 cm	12 cm	18 cm
RPC plane	thickness, cm	1.4	1.4	1.4
	density g/cm^3	0.89	0.89	0.89
	radiation length, cm	32.6	32.6	32.6
	radiation length, fraction	0.043	0.043	0.043
	interaction length, cm	121.3	121.3	121.3
	interaction length, fraction	0.012	0.012	0.012
	mass sampling, g/cm^2	1.25	1.25	1.25
absorber	polypropulene thickness, cm	6.0	12.5	18.0
	polypropylene density, g/cm^3	0.9	0.9	0.9
	polypropylene, rad. length, cm	49.1	49.1	49.1
	interaction length, cm	96.5	96.5	96.5
	air gap, cm	2.0	5.0	7.5
	average density, g/cm^3	0.675	0.643	0.635
	radiation length, fraction	0.122	0.255	0.367
	interaction length, fraction	0.012	0.012	0.012
	mass sampling, g/cm^2	5.4	11.25	16.2
detector	radiation length, fraction	0.165	0.298	0.0.41
	interaction length, fraction	0.062	0.130	0.187
	mass sampling, g/cm^2	6.65	12.5	17.45

Neutrino interactions were generated between planes 10 and 15 of the detector in a cylindrical volume with 10 cm radius. The simulated events sample does, therefore, correspond to a very large unformrm detector with full containment of the produced secondaries.

It is expected that the effect of the final detector volume and/or possible local dead areas will be simulated in the analysis phase by discarding the detector signals outside the active detector volume.

6 Data sets

Data files are stored in a standard ADAMO format [1].

Events were simulated in 10,000 events sets (charged and neutral current interactions). Proper normalization of different files requires, therefore a relative weight of $8.5 = (20-3)/(3-1)$ to be applied to the high energy data files. This will yield an uniform distribution of events between 1 and 20 GeV. A realistic events spectrum corresponding to a selected detector position can be generating by a subsequent application of an energy-dependent weight.

High energy events files have a string $3-20$ embedded in the file name.

Electron/muon neutrino/antineutrino events files are identified by an appropriate string nue/numu/nuebar/numubar at the beginning of the file name.

The absorber thickness used in the detector simulation is identified by a string 6cm/12cm/18cm embedded in the event file.

Events generated with the initial release of NEUGEN3 have 'neugen3' string embedded in the file name.

Different files corresponding to the same detector/beam configuration were generated using different sequences of random numbers as provided by GEANT/CERNLIB. Each sequence is providing a set of 10^9 random numbers. The same sequences were re-used to produce events under different conditions (energy range, detector configuration, neutrino type).

The statistics of the available data sets is summarized in a table below:

Neutrino	Energy	Generator	Absorber	Number of events
ν_e	1-3	NEUGEN2	6 cm	100,000
ν_e	3-20	NEUGEN2	6 cm	100,000
ν_e	1-3	NEUGEN2	12 cm	100,000
ν_e	3-20	NEUGEN2	12 cm	100,000
ν_e	1-3	NEUGEN2	18 cm	200,000
ν_e	3-20	NEUGEN2	18 cm	200,000
ν_μ	1-3	NEUGEN2	6 cm	300,000
ν_μ	3-20	NEUGEN2	6 cm	300,000
ν_μ	1-3	NEUGEN2	12 cm	500,000
ν_μ	3-20	NEUGEN2	12 cm	670,000
ν_μ	1-3	NEUGEN2	18 cm	300,000
ν_μ	3-20	NEUGEN2	18 cm	300,000
$\bar{\nu}_e$	1-3	NEUGEN2	12 cm	100,000
$\bar{\nu}_e$	3-20	NEUGEN2	12 cm	100,000
$\bar{\nu}_\mu$	1-3	NEUGEN2	12 cm	100,000
$\bar{\nu}_\mu$	3-20	NEUGEN2	12 cm	100,000
ν_e	1-3	NEUGEN3	12 cm	100,000
ν_e	3-20	NEUGEN3	12 cm	100,000
ν_μ	1-3	NEUGEN3	12 cm	300,000
ν_μ	3-20	NEUGEN3	12 cm	300,000

The data files are stored in Fermilab mass storage system in a directory /pnfs/minos/para/gaf. Subdirectories 12cm/12cm_neugen3/18cm/6cm contain the data files created with different detector/generator versions.

A Appendix

An example of the input data file is shown below.It was used to generate ν_e events in a detector with 12 cm thick absorber, set number 1, with neutrino energies from 1 to 3 GeV. The following changes need to be made for other data sets:

- to generate more data sets under the same conditions:
  - RNDM card: change RNMD 1 0 to RNDM n 0 to generate events corresponding to a random number sequence number 'n'
  - GAFN card: change the output file name to reflect the random number sequence
- to generate ν_e events with neutrino energies from 3 to 20 GeV (or other range, as needed): change the FLXL card to: FLXL 3. 20.
- to generate other neutrino species: change PFLV card:
  - for ν_μ events : PFLV 12 14 16 -12 -14 -16
  - for $\bar{\nu}_\mu$ events : PFLV 12 -14 16 -12 -14 -16
  - for $\bar{\nu}_e$ events : PFLV 12 -12 16 -12 -14 -16
- to generate events in a detector with different sampling: change 12.5 and 5.0 in the cards below to reflect the desired absorber structure. The resulting absorber consists of '12.5 cm' of polypropylene preceeded by '5 cm' of air

```
RVOL 1='Z1PL' 'Z1PL' 'Z1PL'
RTAG 1='THIC' 'WIDT' 'LENG'
RVAL 1=  12.5  800.   800.

       .....

RVOL 20='R1PL'
RTAG 20='AIR2'
RVAL 20= 5.0
```

- to generate different number of events: change TRIG card to TRIG Ntrig

Example of a FFR file:

```
c LIST - forces FFREAD to echo cards back
c useful to record conditions in log file
LIST
c=================================================================
c general user section
c=================================================================
c
c RUNG - user "run" and "event" numbers
c RNDM - set random number seeds (2 values)
c TRIG - number of events to process
c STAT - if first value = 1 volume statistics are generated (GBSTAT)
c HSTA - standard GEANT histograms (list up to 10)
c        legal values: 'TIME' 'SIZE' 'MULT' 'NTRA' 'STAK'
c PRIN - call gprint() (list up to 10)
c        legal values: 'MATE' 'TMED' 'GEOM' 'VOLU' 'ROTM' 'SETS'
c SAVE - limit information into GAF (not yet implemented)
c        'INIT' 'GEOM' 'EVNT' 'NDIG' 'NHIT' ???
RUNG 101 1
RNDM 1 0
TRIG 10000
STAT 1
HSTA 'TIME' 'SIZE' 'MULT' 'NTRA' 'STAK'
PRIN
SAVE 'INIT' 'GEOM' 'EVNT'
c
c GAFF - output file format (0=ascii GAF, 1=FZ GAF)
c GAFN - output file name
c        (if extension is .xx_gaf then "xx" is replaced by "ie" or "fz")
c HRFN - output histogram file name
c WGAF - 0 = write all events to GAF file
c        1 = only those with non-empty hit or digit tables
c        2 = only those with non-empty hit tables
c
GAFF 1
GAFN 'nue1_12cm.xx_gaf'
HRFN 'gminos.rz'
WGAF 2
c
c MFLX - flux method
c        0 = artifical-flux spectrum of nu_e,nu_e~,nu_mu,nu_mu~,
c            uniform over face.  spectra envelopes the PH2 LE,ME and HE
c            beams such that weights can always be < 1
c        1 = read in Mufson/Miller flux ntuple file created from Jim Hylen's
```

```
c            GBEAM output.  This works for both the near and far detectors.
c        2 = read in Peter Litchfield's flux format for cosmic neutrinos
c            (similar to 1, but energy scale is MeV)
c        3 = read in Hatcher flux format; this format avoids trig overhead
c            of method 1 and fixes some coordinate transformation errors
c            in that code.   Flux is derived form reweighting code of J. Hylen
c        4 = flux of nu_mu's with 1/E spectrum (see FLXL below)
c FFLX - flux method file name (meaningful values depends on method).  For
c        MFLX=1,2,3: input character string denoting name of ntuple file.
c FLXL enu_min, enu_max - imposed flux energy limits
c BCEN beam_x0 beam_y0 beam_z0   - set beam spot center in detector co-ord
c                                  defines center of reference plane
c BSLP beam_dxdz beam_dydz       - set beam slope
c ZREF z_tgt2ref                 - desired z from target to reference plane
c FREF ref_z_nominal             - z tgt2ref used in generating flux file
c MFLV - flavor changing method
c        0 = no changes
c        1 = fixed permutations
c PFLV - flavor permutation map (MFLV=1)  6 values
c        integer value = PDG id for nu_e,nu_mu,nu_tau,nu_e~,nu_mu~,nu_tau~
c        nu_e = 12, nu_mu = 14, nu_tau = 16, anti-neutrino is negative
c MKIN - event kinematics method
c        0 = call usr_kine
c        1 = call hepevt_file_kine (reads "hepevt.dat" STDHEP file)
c        2 = call neugen_kine (integrated NEUGEN package)
c        3 = call single_part_kine (uses /GCKINE/ IKINE and PKINE)
c            IKINE = geant particle #
c            PKINE(1..3) = particle momentum
c            set using KINE card, interactively change with KINE command
c        4 = up- and down- going muons
c        5 = allocated for beam (rock) muon method  - NOT YET IMPLEMENTED
c        6 = allocated for radioactive noise method - NOT YET IMPLEMENTED
c FNDE - find event (meaningful only for MKIN=1)
c        0 = start at beginning of file
c       -n = skip abs(n) events
c       +n = look for event # "n"
c MTDK - tau decay method
c        0 = neugen+tauola (no displaced vertex)
c        1 = GEANT GDECAY (not recommended)
c        2 = LUND performs the decay (GLUDKY_MINOS)
c        3 = NEUGEN+tauola; GEANT displace vertex (zombie/reanimate)
c            by tracking the re-animated tau; substitute tauola's decay
c            products (not initially entered) when tau decays
```

```
c        4 = tauola called by GUDCAY (not yet implemented)
c ROCK - inclusion of rock in allowed interaction region
c         0 = only the detector
c        -1 = only the upstream rock
c        +1 = upstream rock + detector
c CCNC - CC or NC generation
c        -1 = NC + CC
c         1 = CC only
c         2 = NC only
c DKOF - list of IPDG variables NEUGEN should _not_ decay
c QELR - QE or DIS
c        -1 = all
c         0 = QE-like
c         1 = inelastic
c RSCT - intranuclear rescattering 0=off 1=on (use 0)
c TAUB - choose particular tau branching mode
c         0 = all modes
c         1 = tau -> e   only
c         2 = tau -> mu  only
c         3 = tau -> pi  only
c         4 = tau -> rho only
c         5 = tau -> a1  only
c         6 = tau -> K   only
c         7 = tau -> K*  only
c DISG - Deep Inelastic Scattering generator
c         0 = standard Soudan2 DIS
c         1 = PYTHIA/JETSET for DIS - allows charm production
c HQDK - heavy quark decay method
c         0 = NEUGEN/PYTHIA promptly decays heavy Q states (charm hadrons)
c         1 = GEANT propagates heavy Q hadrons, LUND handles decay kinematics
c ACPT - acceptance cuts on NEUGEN events (see kine/accept_neugen_kine)
c         0 = keep all legal NEUGEN events
c         1 = require event to contain heavy quark (charm or bottom)
c SAVT - list of event # (idevt) in which to save intermediate track info.
c        Saved to StdHep's /HEPEVT/ (limited to 4000 lines).  List can
c        contain 100 events; pairs so negative values denote a range.
c C2ND - threshold (GeV) for saving secondary particle to /HEPEVT/;
c        one threshold per GEANT process.  If the value is positive
c        then any particle with PTOT greater than threshold saves all the
c        secondaries in that interaction; if negative then only those
c        particles over threshold are recorded.
c        By repeating the card one can overwrite individual values
c        after setting an initial default.  ie.
```

```
c            C2ND 60*0.020
c            C2ND 9=0.150 10=0.150 11=0.150
c        sets a limit of 20MeV for all processes except BREM,DRAY,ANNI
c        which use 150MeV.  (default is 0.150).
c        Process are:
c           1='NEXT'  2='MULS'  3='LOSS'  4='FIEL'  5='DCAY'
c           6='PAIR'  7='COMP'  8='PHOT'  9='BREM' 10='DRAY'
c          11='ANNI' 12='HADR' 13='ECOH' 14='EVAP' 15='FISS'
c          16='ABSO' 17='ANNH' 18='CAPT' 19='EINC' 20='INHE'
c          21='MUNU' 22='TOFM' 23='PFIS' 24='SCUT' 25='RAYL'
c          26='PARA' 27='PRED' 28='LOOP' 29='NULL' 30='STOP'
c          31='LABS' 32='LREF' 33='SMAX' 34='SCOR' 35='CKOV'
c          36='REFL' 37='REFR' 38='SYNC' 39='STRA'
c
c ATMD - (MKIN=4 only) direction of muons
c         0 = up
c         non-zero = down
c ATMF - up muon spectrum histogram file
c ADMF - down muon spectrum histogram file
c

c 1/E flux from 1.0 GeV to 3.0 GeV
MFLX 4
c FFLX 'override_file.name'
FLXL 1.0 3.0

MFLV 1
PFLV 12 12 16 -12 -14 -16
MKIN -2
FNDE 10
MTDK 3
RSCT 0
ROCK 0

c BCEN +131.06 326.05

c
c restrict the generated vertex position
c     PLNL  - plane limits first & last
c     FIDB  - max radius around the beam axis
c     FIDZ  - max radius around the detector z axis (ie. coil)
c
PLNL 10 15
```

```
c FIDB 50.
FIDZ 10.

c
c SXYZ - save step information in JXYZ structure during GUSTEP call
c        0 = nothing stored (use this during batch runs)
c       -x = store only charged particles
c        1 = store only while entering active detector volume
c        2 = store when entering any volume
SXYZ 0
c
c================================================================
c detector geometry section
c================================================================
c
c SUPR - overall supermodule organization
c        -1 = near LST detector   +1 = far LST detector
c        -2 = near FLS detector   +2 = far FLS detector
c        -3 = near RPC detector   +3 = far RPC detector
c     +4 = calibration detector

c
c NORF - override Near/Far as set by SUPR, leave geometry unaffected
c        (near=negative values, far=positive value, calibration = 0)
SUPR +3
C NORF 2
c
c VHAL - detector hall volume size (half lengths in cm)
c HXY0 - x-y offset of hall centerline in global coordinates
c
c VHAL  700. 700. 10159.0
c HXY0 0. 0.

c up to 15 independent supermodules can be defined
c NPLS - total number of active planes in each supermodule (end list w/ 0)
c SSPA - additional space up(down)-stream of the first(last) plane
c        of a supermodule (allows for magnet coils); 2 values/supermodule.
c        The default grants 2m extra space upstream of first module to
c        allow for "walk space".
c SX0,SY0 - x,y offsets of supermodule relative to centerline of HALL volume
c NPLS    240    240    0    0
c SSPA 250. 50. 2*50.  2*50.
c SSPA    4907.3 0. 0.
```

```
c SX0      0.     0.    0.
c SY0      0.     0.    0.
c
c CSET - coil winding placements for supermodule
c        0 = no coils
c        1 = center bus; return bus in (-x,-y) corner
c        4 = center bus; return bus bars in 4 corners
c        8 = center bus; return bus bars every 45degrees
c       10 = dipole configuration; 4 bus bars at 80% of half-length;
c            horizontal connects at front/back faces
c CCUR - B field map multiplier for supermodule (-1=focus mu-,+1=focus mu+)
c RMAG - coil bus bar cylinder radius
c CMAG - coil bus bar clearance
c BFLD - maximum expected field in KGauss
c CSET  15*1
CCUR  15*-1.
RMAG 15.
CMAG 22.5
BFLD 20.0
c
c planes in the supermodule are grouped as (passive,active) planes
c each supermodule is made up of identical integral "modules"
c each module can be made of up to 16 pairs
c the number of pairs set in SiPA should integrally divide NPLS value
c SiPA - (Super)module "i" (hex value 1 to F) "pair" list (up to 16 pairs)
c        terminate the list with the string '....' (can be 17th value)
c        a "pair" takes the form 'PjAk' where:
c           P - passive plane type
c               'A'=aluminum       'B'=magnetized iron
c               'C'=concrete       'G'=glass
c               'K'=skip (air)     'P'=Pb (lead)
c               'S'=steel (no B)   'Z'=user specified (cf ABSx cards)
c           j - "instance" character (1..9,A..Z)
c               distinquish between different configurations
c           A - active plane type
c                'L' = LST = limited streamer tube (also proportional tubes)
c                'F' = FLS = fiber in liq scint (also plastic scint)
c                'R' = RPC = resistive plate chambers
c                'T' = TST = test planes (placeholder for user geometry)
c           k - "instance" character (1..9,A..Z)
c        any combination of passives and actives is permissible
c        different active can be included in the same module
```

```
c SiRM - (Super)module "i" rotation matrix string (one char/pair)
c        only the active planes are rotated
c              cell direction   readout end   increasing cell #
c        'X' = horizontal           -x         (-x,-y) -> (-x,+y)
c        'Y' = vertical             +y         (-x,+y) -> (+x,+y)
c        'U' = 45deg             (-x,+y)       (-x, 0) -> ( 0,+y)
c        'V' = 45deg             (+x,+y)       ( 0,+y) -> (+x, 0)
c SiX0 - (Super)module "i" x shift of plane in "module"
c SiY0 - (Super)module "i" y shift of plane in "module"
c
c example:
C S1PA 'B4F4' 'B4F4' 'B4F4' 'B4F4' 'B4F4' 'B4F4' 'B4F4' 'B4F4' '....'
C S1RM 'XYUVXYUV'
C S2PA 'B1L2' 'B3F4' 'B5R6' 'A1T1' '....'
C S2RM 'XYXY'
c shift the 4th plane in every module of the 1st supermodule
C S1X0 4=10.0
C S1Y0 4=10.0

c
c  a detector of 100 RPC planes with 25 cm of polyprop between them
c
SUPR +3
CSET 0
VHAL  700. 700. 10159.
NPLS 100 100 100 100 0
SSPA 100.0 25.0 25.0 25.0 25.0 25.0 25.0 100.0
S1PA 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' '....'
S2PA 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' '....'
S3PA 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' '....'
S4PA 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' 'Z1R1' '....'
S1RM 'XYXYXYXY'
S2RM 'XYXYXYXY'
S3RM 'XYXYXYXY'
S4RM 'XYXYXYXY'

IVOL 1='Z1PL' 'Z1PL' 'R1PL'
ITAG 1='MEDI' 'SHAP' 'SHAP'
IVAL 1='POLY' 'BOX ' 'BOX '

RVOL 1='Z1PL' 'Z1PL' 'Z1PL'
RTAG 1='THIC' 'WIDT' 'LENG'
RVAL 1=  12.5  800.   800.
```

```
RVOL 10='R1PL' 'R1PL' 'R1XT' 'R1CB' 'R1CL' 'R1CV' 'R1GV' 'R1GB'
RTAG 10='WIDT' 'LENG' 'WIDT' 'WIDT' 'WIDT' 'WIDT' 'WIDT' 'WIDT'
RVAL 10= 802.   802. 100.24 100.0  100.0  100.0  100.0  100.0

RVOL 20='R1PL'
RTAG 20='AIR2'
RVAL 20= 5.0

c Volumes are labelled 'PjTT' where:
c    'Pj' is the plane type and instance (either passive or active)
c    'TT' is one of:
c       'PL'  plane      clipping volume
c       'BX'  box        artifact for extrusion division (no user adjustment)
c       'XT'  extrusion  extrusion volume divided out of BX volume
c       'CB'  comb       forms cell walls within extrusion
c       'CV'  cover      forms cell top
c       'CL'  cell       cell volume displaces comb, touches cover
c       'GV'  gap CV     dead region between cover and extrusion
c       'GB'  gap CB     dead region between comb and extrusion
c       passive planes only have 'PL' specifications
c Each volume has a number of characteristics
c    name             type       volume  description/legal values
c    'SHAP' shape     hollerith  '??PL'  'BOX' 'TUBE' 'PGON' (PGON=octogon)
c    'MEDI' medium    hollerith   any    first 4 char of tracking medium
c    'WIDT' width     real        any    transverse size of volume
c    'THIC' thickness real        any    depth of volume in z
c    'AIR1' airgap(1) real       '??PL'  air space on front side of plane
c    'AIR2' airgap(2) real       '??PL'  extra space on back side of plane
c    'BMAP' bmap      integer    'B?PL'  magnetic field map (0=none)
c    'CHIL' children  integer     ----   # of sub-volumes
c                                '??XT'  1=comb alone,2=CB,CV,3+=CB,CV,GB,GV
c    'DIGT' digittype integer    '??PL'  digitization scheme
c                                        1=LST,2=FLS,3=RPC
c Characteristics are set as triplets (volume name,attribute,value)
c Real valued attributes are set using the RVOL,RTAG,RVAL cards
c Integer/Hollerith attributes use IVOL,ITAG,IVAL cards.
c Up to 1500 triplets of each type can be set.
c An instance value of '*' sets the default.
c Note: re-issuing the same card name restarts the sequence and potentially
c overwrites values.  Users must explicitly give an offset.  Alternatively,
c values can be continued by placing them on lines immediately following
c the named card with no intervening keys.
```

```
c example:
C RVOL 'F4PL' 'F4XT' 'F4XT' 'F4CB' 'F4CB' 'F4CL' 'F4CL'
C RTAG 'THIC' 'THIC' 'WIDT' 'THIC' 'WIDT' 'THIC' 'WIDT'
C RVAL   2.0    2.0   66.5    1.7   66.4    1.7   1.971875
C IVOL 'F4CB' 'F4XT'
C ITAG 'CHIL' 'CHIL'
C IVAL    32      1
C RVOL 10='R2CL' 'R2CB' 'R2GV' 'R2GV' 'R2GB' 'R2GB'
C RTAG 10='THIC' 'THIC' 'THIC' 'WIDT' 'THIC' 'WIDT'
C RVAL 10=0.2      0.3    0.2    7.8    0.5    8.0
C IVOL 10='R2GV' 'R2GB' 'R2XT' 'R2GV' 'R2GB'
C ITAG 10='MEDI' 'MEDI' 'CHIL' 'SHAP' 'SHAP'
C IVAL 10='RPC*' 'RPC*'     4  'BOX ' 'BOX '
c RVOL 'F4PL'
c RTAG 'AIR2'
c RVAL 0.4
c
c Of special interest to the "average" user might be how one modifies
c the B field map used by that plane.  All "B"-type planes of the
c same "instance" use the same field map; if you need to mix different
c maps in the same setup you'll need to construct a duplicate physical
c configuration.  The '?' gets replaced by the instance value, and
c the "bmap#" must be a positive integer.  Map 0 is the z-independent,
c azimuthally symmetric, phi-only field.  Additional maps should be
c added interfaced through the GUFLD routine (not replace it).
C IVOL 'B?PL'
C ITAG 'BMAP'
C IVAL  bmap#
c
c=================================================================
c detector materials/tracking section
c=================================================================
c AUTO - override automagic computation of tracking parameters
c         0 = use manual tracking limits (see LBL_MTRK)
c         1 = use normal computation
c SLST,SFLS,SRPC,SEMU,SFE - tracking cuts for active detector volumes (and Fe)
c  these do not take effect unless AUTO = 0
c  negative values for 1,2,3,5 are still computed using auto scheme
c  unless explicitly set 6,7,8,9 are taken from general GEANT physics cards
c    SXXX( 1) = tmaxfd - max ang deviation due to B field (in degrees)
c    SXXX( 2) = stemax - max step permitted (cm)
c    SXXX( 3) = deemax - max fractional energy loss in 1 step [0..1.]
c    SXXX( 4) = epsil  - boundary crossing precision (cm)
```

```
c    SXXX( 5) = stmin  - minimum step size from (e-loss,scattering,Bfield)
c    SXXX( 6) = idray  - delta ray mechanism (see PHYS001)
c    SXXX( 7) = iloss  - continuous energy loss mechanism
c    SXXX( 8) = dcute  - cutoff between continuous & delta-ray by e
c    SXXX( 9) = dcutm  -   "      "       "             "       by mu
c CLST,CFLS,CRPC,CEMU,CFE - cutoff values for active volumes (and iron)
c    cutgam cutele cutneu cuthad cutmuo bcute bcutm dcute dcutm ppcutm
c FLST,FFLS,FRPC,FEMU,FFE - physics flags for active volumes (and iron)
c    pair comp phot pfis dray anni brem hadr munu dcay loss muls stra
C SXXX tmaxfd stemax deemax epsil stmin idray iloss dcute dcutm
C CXXX cutgam cutele cutneu cuthad cutmuo bcute bcutm dcute dcutm ppcutm
C PXXX pair comp phot pfis dray anni brem hadr munu dcay loss muls stra
c LSTD,RPCD - gas density of LST or RPC mixture
c LSTW,RPCW - gas mixture fractions (by volume)
c  XXXW(1) = isobutane
c  XXXW(2) = CO2
c  XXXW(3) = argon
c  XXXW(4) = SF6
c  XXXW(5) = Freon13b1
c MXST - maximum steps GEANT will track a particle
C AUTO 0
C SLST -5.0 -0.01 -0.01 0.005 -0.005 DRAY LOSS CUTS(8) CUTS(9)
C SFLS -5.0 -0.01 -0.01 0.005 -0.005 DRAY LOSS CUTS(8) CUTS(9)
C SRPC -5.0 -0.01 -0.01 0.005 -0.005 DRAY LOSS CUTS(8) CUTS(9)
C LSTD 1.205e-3
C LSTW .090 .700 .210 .000 .000
C RPCD 1.205e-3
C RPCD .300 .000 .700 .000 .000
SFE 4=0.001
MXST 200000
c
c Allow the user to create their on passive absorber material
c ABSN - mixture name (*must* be 20 char or less, FFREAD apparently doesn't
c        catch overlong strings; on some machines this causes core dumps)
c ABSA - list of element's A values (up to 10, end list w/ 0)
c ABSZ - list of element's Z values (up to 10, end list w/ 0)
c ABSW - list of element's fraction by weight (up to 10)
c ABSD - mixture density
c     12345678901234567890
ABSN 'LUCITE CH2CCH3CO2CH3'
ABSA 1.   12.   16.    0.
ABSZ 1.    6.    8.    0.
ABSW  .08   .60   .32  0.
```

```
ABSD 1.16
c
c LIQD - liquid scintillator density (Bicron sez: .86, MACRO sez: .8222)
LIQD 0.86
c================================================================
c active detector section
c================================================================
c
c FATL - fiber attenuation lengths (short+long) in cm
c FATN - fiber attenuation normalizations (short+long)
c STUB - fiber pig-tail beyond extrusion end
c PEMU - photo electrons in normalization calculation
c ELMU - dedx energy loss for muon in normalization calculation
c FATL 135. 1100.
c FATN 1.0  0.66
c STUB 100.
c PEMU 15.6
c ELMU 0.0028
c
c================================================================
c standard GEANT physics data card section
c================================================================
c
c  Turn on various PHYSICS processes.
c
c -- avoid double counting of delta-rays and energy loss
c -- restricted fluctuations DRAY=1,LOSS=1
DRAY 1
LOSS 1
c -- no explicit delta rays DRAY=0,LOSS=2
c DRAY 0
c LOSS 2
c -- no fluctuations DRAY=1,LOSS=4
c DRAY 1
c LOSS 4
ANNI 1
BREM 1
COMP 1
DCAY 1
HADR 1
MULS 1
MUNU 1
PAIR 1
```

```
PFIS 1
PHOT 1
c
c 100KeV cuts
c
CUTS 10*.0001
c
c===============================================================
c signal end off FFREAD input
c===============================================================
END
```

References

[1] GMINOS and Labyrinth: simulation and reconstruction software of MINOS experiment. The Web site *http://www-numi.fnal.gov/offline_software/labyrinth/index.html* contains the description as well as the installation procedure.

[2] Hugh Gallagher, Tufts University, private information. Writen notes forthcoming..